Assessment of the edaphic community in a *Eucalyptus globulus* Labill. allotment at Santa Justa's mountain

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Todas as correções determinadas pelo júri, e só essas, foram efetuadas.

O Presidente do Júri,

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Dissertação submetida a Faculdade de Ciências da Universidade do Porto para a obtenção do grau de Mestre em Ecologia e Ambiente, da responsabilidade do Departamento de Biologia.

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Resumo

As plantações intensivas de *Eucalyptus* sp. tornaram-se comuns em Portugal. A presença desta árvore, exótica, altera as propriedades do solo e influencia as comunidades bióticas. O objetivo do presente estudo foi avaliar os efeitos da vegetação na comunidade de artrópodes edáficos e caracterizar o solo numa área de plantação de *Eucalyptus globulus* na Serra de Santa Justa, Valongo, em exploração há cerca de 30 anos. Foram selecionadas 6 zonas (4 dentro da área de estudo e duas fora) com diferentes cobertos vegetais. Utilizaram-se armadilhas de captura *pitfall* para a recolha da comunidade edáfica e foi efetuada a caracterização física e química do solo (pH, condutividade, capacidade de retenção de água e matéria orgânica) e a avaliação da riqueza do banco de sementes que existia em cada zona em dois períodos distintos (outono e primavera). O solo apresentou um carácter ácido em ambas as estações do ano amostradas. Os valores da condutividade elétrica variaram entre zonas e estações do ano. As percentagens de matéria orgânica tendem a ser mais elevadas nas zonas onde a percentagem de *Eucalyptus* sp. também é maior. Os valores de capacidade de retenção de água foram mais elevados nas zonas com menor percentagem de *Eucalyptus* sp. ou nas zonas onde esta espécie está reduzida a touças (A, C e D). O mesmo aconteceu no banco de sementes em que o número de sementes/espécies germinadas foi mais elevado nas zonas com ausência de cobertura de *Eucalyptus globulus* (A e C). A diversidade e a equitabilidade da comunidade edáfica seguiram a tendência oposta, nas zonas com maior percentagem de cobertura de eucalipto foram as zonas que apresentaram os valores mais elevados dos índices de Shannon e Pielou (B, E e F). Apesar de os resultados serem semelhantes entre as estações do ano amostradas, a sazonalidade parece ter um papel importante na comunidade edáfica uma vez que os valores dos índices de diversidade e equitabilidade, a abundância e a riqueza específica apresentam variação entre o Outono e a Primavera. A DCA não demonstrou relações entre os *taxa* identificados e os locais de amostragem. A classe Collembola foi a mais representada em ambas as estações com valores de abundância muito superiores às restantes classes. No Outono, a classe Insecta foi a segunda com maior representatividade enquanto que na Primavera esse lugar foi ocupado pela classe Arachnida. Com a evolução da área de estudo e o esforço na conversão em floresta autóctone pelas autoridades locais, seria de extrema importância a continuidade deste tipo de estudos para se perceber a evolução da diversidade da comunidade edáfica à medida que o coberto vegetal se vai alterando.

Palavras-chave: *Eucalyptus globulus,* caracterização do solo, fauna edáfica, cobertura vegetal

Abstract

Eucalyptus sp. intensive plantations became common in Portugal. The presence of these exotic trees switches the way soil is used and influenced changes in the biotic communities and in soil properties. Thus, the objective of this study is to evaluate the effects of the vegetation matrix in the edaphic arthropod community and to characterize the soil of a *Eucalyptus globulus* area in Serra de Santa Justa, Valongo, which has been explored for about 30 years. For this purpose, 6 zones (4 inside the area and 2 outside) were chosen with different vegetation coverage. The edaphic community was identified using pitfall traps installed in two different seasons – autumn and spring. Additionally, a physical and chemical characterization of the soil was conducted (pH, conductivity, water holding capacity and organic matter) and an evaluation of seed bank of the soil was carried out to achieve the dormant plants richness in the studied ecosystem. Soil presented an acidic nature in both seasons. Electrical conductivity values varied among zones and between seasons. Organic matter content tends to be higher in the zones with more *Eucalyptus* sp. coverage. Water holding capacity seemed to be slightly influenced by *Eucalyptus globulus* presence as its values were higher in the zones with less *Eucalyptus* sp. coverage or where the trees were reduced to stumps (A, C and D). The same happened with seed germination that occurred more in the areas with no *Eucalyptus* sp. coverage (A and C). The edaphic community diversity and equitability followed the opposite trend, the zones with more *Eucalyptus* sp. coverage were the zones with highest Shannon and Pielou indexes values (B, E and F). Despite these results, seasonality also play an important role as differences of indexes, abundance and richness values on autumn and spring are quite substantial in most of the zones. Detrended Canonical analysis was not conclusive to assess any kind of relation between the sampling sites and the *taxa*. Collembola were by far the most represented organisms in both seasons. Insecta is the second class most represented on autumn and on spring it changed for class Arachnida. With the evolution of that area to autochthonous forest promoted by local authorities, further edaphic community studies might be interesting to apply to understand their evolution as the vegetation cover changes.

Keywords: *Eucalyptus globulus,* soil characterization, edaphic fauna, vegetation coverage

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List of Abbreviations

DCA – Detrended Correspondence Analysis

EC – Electrical Conductivity

PSeP – Parque das Serras do Porto

OM – Organic matter

WHC – Water Holding Capacity

Introduction

Mankind has always used wood as an important resource for different human activities. In Portugal, especially since the early maritime discovery periods the search for timber introduced a huge pressure in the forestry ecosystems and a depletion of forest land cover (Ribeiro and Delgado, 1868, Reboredo and Pais, 2014). Besides, the continuous augmentation of human population, the need of soil transformation into arable land and pastures and the beginning of the industrialization improved the country deforestation. In the early of the 18th century only about 7% of the national area had forest coverage (Fernow, 1907; Reboredo and Pais, 2014). With the creation of the state Forestry Services and also private initiatives at the end of the 19th century, the previous trend began to change (Reboredo and Pais, 2014). In 1938, the Reforestation Plan, created by the Portuguese government intended to expand the forest area through the incentive of tree planting by silvicultural technics, as it was noticed that the forest had economic value (Radich and Baptista, 2005; Alves et al., 2007). Along with *Pinus* sp., *Quercus suber* L., *Quercus rotundifolia* Lam. and other species, the *Eucalyptus* sp. plantation was implemented (Reboredo and Pais, 2014).

The occupation of the Portuguese territory with *Eucalyptus* sp. trees kept a slight growth until the 50's of the twentieth century (Alves et al., 2007; Cerasoli et al., 2016). At that time and due to economic strategies, the cellulose industry began to rise in the country and land occupation by *Eucalyptus sp.* significantly increased (Alves et al., 2007). According to the last National Forest Inventory, 2010, these exotic trees-species already represent the biggest forest coverage percentage, 26%, in the country (ICNF, 2013). Alves and Pereira (1990) considered *Eucalyptus globulus* Labill. as the one which showed more economic advantages, of all the *Eucalyptus* sp. already planted in the country, and was encouraged to be planted with agreements of the Portuguese government, the industrial sector and the bank sector (Alves et al., 2007). *Eucalyptus globulus* ~~Labill.~~, naturals from Australia and Tasmania (Alves and Pereira, 1990) and was ~~were~~ introduced in Portugal in 1854 (Coutinho, 1886) or 1859 (Pimentel, 1884). Due to its high capacity to adaptation to different environmental conditions and its fast growth rates, this species is capable to develop in diverse areas. Namely, in the North part of the country, specially Porto-Aveiro-Coimbra axis, the territory has extensive planting areas of this species (Alves et al., 2007).

Albeit these plantations being a significant economic source for Portugal, their effects on the ecosystems were notable and the real assessment of the impacts of this exploitation is becoming known (Fabião et al., 2007; Madeira et al., 2007; Onofre, 2007).

Madeira (2007; 2015) pointed the extraction of the *Eucalyptus* sp. logging residues from the fields as one of the main factors for the extraction of nutrients and soil impoverishment and changes in the hydrological cycles have also been studied at different plantation areas of *Eucalyptus* sp. According to David (2007), a study conducted in Portugal territory revealed that the hydrological stability in *Eucalyptus* sp. areas is achieved between 3 and 4 years after planting, but these numbers rise to 4 or 5 years for logged trees. Depending on the rotation crop periods, the stability of the hydrological cycle in the ecosystem can be difficult to achieve. One approach to interpreting the impacts of the plantations can be by studying the edaphic arthropods communities that occur in these ecosystems.

Arthropods are the largest and most diversified animal group (Jeffery et al., 2010), and it is estimated that soil arthropods can correspond to 85% of all described soil organisms (Bagyaraj et al., 2016). Their diversity allows them to cover several different habitats playing crucial functions as predators, decomposers, preys, parasites, herbivores, and pollinators (Lavelle et al., 2006; Pereira et al., 2014). These different functions allow them to bind~~ing~~ several ecosystem~~s~~ layers which permit to classify them as "soil engineers" (European Union, 2010). Also, they are relatively easy to sample (Vandewalle et al., 2010), with different methodologies described according to the scope of the study (Gotelli and Colwell, 2001; European Union, 2010). In the literature, there has been a rising showing that edaphic arthropods can be used as bioindicators providing information about different ecological variations in different types of environment and under different types of stresses (Battigelli, 2000; Antunes et al., 2008; André et al., 2009; Antunes et al., 2009; Pereira et al., 2014). Besides their presence, the relations and the dynamics that these organisms can establish give information about the stability of the ecosystem (Moretti and Legg, 2009). The presence of predators, such as spiders, pseudoscorpions and centipedes, can indicate a more complex food chain and a high richness ecosystem. On the other hand, a scenario where only detritivores are present and a lack of predator is observed may indicate that the ecosystem was disturbed or that a succession process is initiated (Scheu and Schulz, 1996; Bagyaraj et al., 2016).

The higher or lower presence of vegetation also has been described as a factor that affects the edaphic communities. The presence of a litter layer and an understory canopy may influence the edaphic communities since parameters as humidity and direct light change are important for this community (Swarts, 2006). Some studies already refer that there might be a connection between the kind of edaphic arthropod community and the understory canopy (Scheu and Schulz, 1996; Schaffers et al., 2008; Santos, 2017). Other authors suggest that the vegetation composition can also have a strong influence in the composition and abundance of edaphic communities (Ratsirarson et al., 2002; Randlkofer et al., 2010). Usually, *Eucalyptus* sp. plantations are associated with low diversity and density of understory coverage due to the change of the hydrologic regimes (Soares et al., 2007) and the production of allelopathic substances by this tree-species (Zhang and Fu, 2009; Chu et al., 2014). Allelopathy is even connected to interfere in the presence of some arthropods and its functions. Swarts (2006) indicate that these substances may be responsible for Collembola and mite's presence deficit during the first stages of *Eucalyptus* sp. litter decomposition.

As an exotic plant, *Eucalyptus globulus* inputted a new forest arrangement in Portugal. Natural predators are already present in the country (*Leptocybe invasa* - Hymenoptera (Branco et al., 2006), *Thaumastocoris peregrinus* - Hemiptera (Garcia et al., 2013), *Gonipterus platensis* – Coleoptera (Reis et al., 2012)) with the possibility of interference with the autochthonous species (Bagyaraj et al., 2016). However, how they adapt and influence the autochthonous species is a factor that should be considered in biodiversity and ecological studies. *Eucalyptus* sp. farming requires a lot of machinery and many physical and chemical impacts on the soil have already been described. The litter removal after logging implicates a decrease in several nutrients such as calcium, magnesium, and potassium (Madeira, 2007; 2015). Also, this litter removal and the different soil handling technics can be related to soil erosion (Fernández et al., 2004; Silva et al., 2007). The intensive exploitation, and a short period of rotation (≈12 years) do not allow the ecosystem to enable its physical structure to achieve complexity (Madeira, 2007; 2015). This fact is known for interfering strongly in the soil dynamics not allowing to understand which factor most affect the ecosystem: the tree or the managing processes (Madeira et al., 2007). According to these, it is important to show to local authorities the necessity to recover these areas to a typical autochthonous forest instead of privileging an exotic tree that is not considered invasive by the Portuguese law (Dec Lei nº 565/99 de 21 de Dezembro) but in which this status creates controversy among the Portuguese scientific community (Invasoras.pt, 2014a). Also, it is important to demonstrate the possibility of using edaphic arthropods as indicators of forest ecological conditions and their relationship with vegetation cover.

The main scope of this study is to evaluate the effects of the vegetation matrix in the edaphic arthropod community and soil characterization in a *Eucalyptus globulus* area. This area has been explored for about 30 years, through the analysis of the arthropod and vegetation communities in six different zones. Additionally, a physical and chemical characterization of the soil was conducted. Moreover, an evaluation of seed bank of the soil was carried out to achieve the dormant plants richness in the studied ecosystem.

Material and Methods

Study site

The study was conducted in an *Eucalyptus globulus* allotment (≈ 40 ha) in Santa Justa's mountain, located in Valongo village, in the northwest of Portugal (fig. 1). Valongo is a region characterized by an Atlantic-Mediterranian climate, with an average of temperatures between 12.5ºC and 15ºC and the precipitation values are from 1200 mm/year to 1800 mm/year. Santa Justa's mountain is inserted in the recently created *Parques das Serras do Porto (PSeP*). *PSeP* is an integrated conservation project which joins three counties Gondomar, Paredes and Valongo and a group of several mountains: Santa Justa, Pias, Castiçal, Flores, Santa Iria and Banjas (Porto, 2017). *PSeP* has an area of about 5985 ha, with a high dominance of *Eucalyptus* sp. plantations (69%) (Porto, 2018).

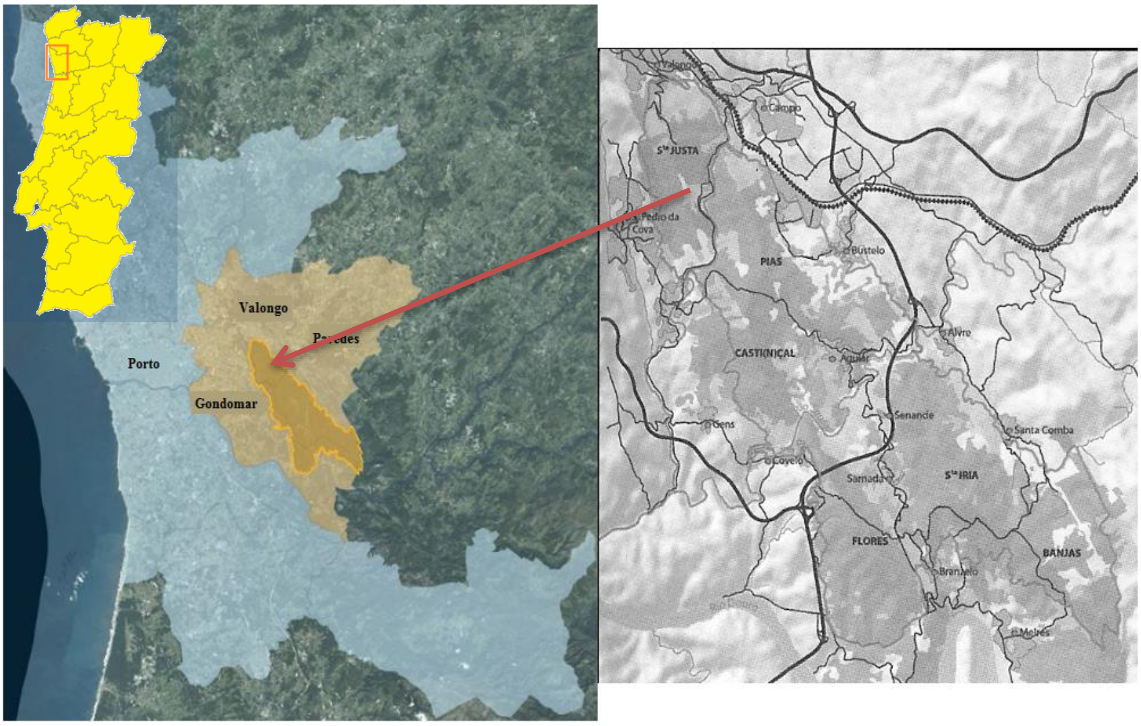


Figure 1 - Location of the study area in the metropolitan Porto area (left) and in PSeP (right)

The 40 ha selected to conduct this study belong to the local municipality with the owner intention of reconverting the area to native forest which allows the present study to be the first characterization work before all the process begins. The study area is located from the top to the middle of the hill, with a high sun exposure and an accentuated slope (18-36 %) (Porto, 2018). Besides the large presence of *Eucalyptus* sp. some pine trees (the southern part) and some oak trees (to the east) near the edges of the area are observed. Beyond the northern edge *Acacia* sp., an invasive species, was sighted, and in some parts with considerable number of individuals. In order to conduct a characterization of the entire area, and due to the homogeneous presence of *Eucalyptus globulus* trees, 4 zones (A, B, C and D, fig. 2 and table 1) were chosen inside the allotment with different trees growth phases. Another zone (E) was chosen next to the northern part of the allotment, with older *Eucalyptus* trees and with a more diverse vegetation cover (fig. 2 and table 1). The F zone was also selected outside the allotment, close to E, with a high presence of *Hakea sericea*, an invasive species highly disseminated in Santa Justa mountain (fig. 2 and table 1). This selection may enable to interpret differences among the zones and understand if any ecological niche exists.

For conducted this study, two sampling periods were considered, autumn and spring, which, according to the literature is stated as the two periods when edaphic arthropods are more active (André et al., 2009).

Table 1 - Description of the 6 study zones of the project

Location	Zones	Zone Characterization
Inside the allotment	A	Cut trees for *in situ* assay: stumps inoculated by fungus
	B	*Eucalyptus globulus* young trees
	C	Young *Eucalyptus globulus* trees with the presence of stones agglomerates
	D	*Eucalyptus globulus* stumps with sprouts
Outside the allotment	E	Grown *Eucalyptus globulus* trees with other species (reference area)
	F	Grown *Eucalyptus globulus* trees with invasive plant *Hakea sericea*

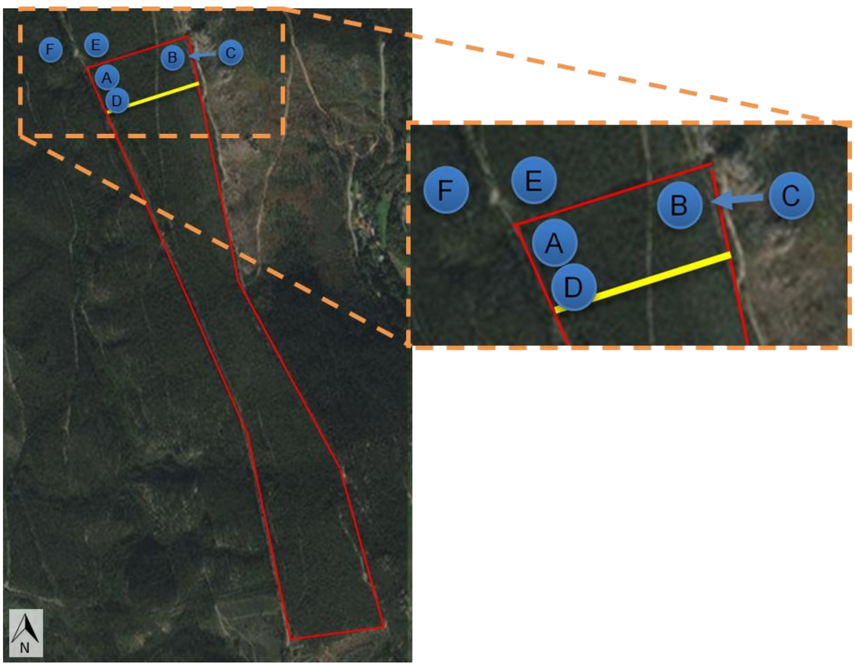


Figure 2 - Total area of the study allotment (40 ha) in Santa Justa's mountain with representation of the six study zones

Vegetation cover

A vegetation characterization was conducted in each sampling zones, with an identification of all the species observed in an area of 1 m^2 around the sampling area (Bunning et al., 2016). The analysis of vegetation cover was done in percentages for each species observed (> 5 %) in each site with the purpose to understand the influence of the vegetation cover on the edaphic communities.

Seed bank assessment

To assess the seed bank viable in the soil, three soil samples were collected from each sampling zone. With a shovel, 10 cm of the top soil was collected to plastic bags and transport to the laboratory. In the laboratory, soil samples were placed in boxes and watered to increase the moisture in the soil. Soil was maintained in a climatic growth chamber set for spring temperatures (21ºC and 14h light exposure) (Gonzalez and Ghermandi, 2012). Every two days, the soil was watered to guarantee the soil moisture, and was observed to register the seedling appearance.

Soil physical and chemical characterization

In each sampling zone four soil replicates were collected from the topsoil layer (upper 10 cm), and passed through a 4 mm sieve, to discard coarse materials. In laboratory, a physical and chemical soil characterization were conducted measuring the pH, conductivity, water holding capacity and organic matter in each soil replicate. Soil pH was measured in a soil water suspension of 10 g of soil mixed with 50 mL of distilled water. After 15 minutes shaking and 1 hour resting, pH values were determined using a multi-parametric probe (FAO, 1984). Soil conductivity (µS/cm) was assessed, in the same pH solutions after they rested over the night, using a conductivity probe (FAO, 1984). Soil Water Holding Capacity percentage (%WHC) was determine by using cups which bottom had been removed and replaced by filter paper. After adding soil till half of their height, the cups were sunk for three hours in a tray filled with water. After this period, the samples were collected and left to drain the excess of water and weighted. Then, they were set in an oven at 60 ºC till a constant weight was achieved. The WHC (%) was determined using Motsara and Roy's (2008) method described in FAO guide. To measure organic matter content (%) the loss-on-ignition method was used. This consists at weighting 20 g of soil to crucibles and incinerate them in a muffle at 450 ºC for 8 h. After this procedure samples were weighted and the content of organic matter was calculated according to weight loss described in Rowell (2000).

Edaphic communities' characterization

In each sampling zones, four pitfall traps were placed totalizing 24 pitfall traps in the study area per season (Siewers et al., 2014). The pitfalls were made with plastic bottles bottoms with ≈ 10 cm of height. This traps were bury in the soil in the open side in the soil surface and had been filled with ≈ 100 mL of formaldehyde (4%v/v) and some detergent drops, in order to reduce the surface tension and allow the organisms to sink to the bottom (André et al., 2009; Santos, 2017). Traps were covered with stones and small pieces of wood to minimize rainfall entrance, as well as prevent the capture of small vertebrates and human disturbance. The pitfall traps remained in the field for 11 days (Antunes et al., 2009; 2013). After this period the content of the pitfall traps was collected and transferred for individual flasks filled with 70% v/v alcohol solution to preserve the organisms.

In the laboratory, the organisms were sorted from the remaining material and stored in individual flasks. For each sample, all the adults organisms were considered, and only the identifiable juveniles were considered for the data analysis. The taxonomic identification was performed to the family level, using specific identification (Barrientos, 1988; Chinery, 1993; Chinery, 2007; Goulet and Huber, 1993; Roberts, 1995; Zhang, 2011; Bradley, 2013; Soil Biodiversity UK, http://soilbiodiversityuk.myspecies.info/; The University of British Columbia, B.R.C., Mites and other microarthropods, http://www.zoology.ubc.ca/~srivast/mites/index.html; NaturData, biodiversity online, http://naturdata.com/; Encyclopedia of life, Available from http://eol.org/) and the total number of individuals of each taxon was recorded. All the organisms belonging to Diptera order were not considered to this study.

Data analysis

The edaphic arthropods community structure and physical and chemical soil parameters were analysed through descriptive statistical methods using Microsoft Excel® (Microsoft, 2018). Through this software abundance, richness, Shannon-Wiener Diversity Index and Pielou Equitability Index was determined for each pitfall replicate, allowing posterior analysis between zones, seasons and other parameters. To assess the arthropods variations between seasons, their distribution and assemblages of the *taxa* with the replicates a Detrendend Correspondence Analysis (DCA) was performed using Canoco 4.5 (ter Braak and Smilauer, 2002) for each sampling season.

Results

Soil physical and chemical characterization

Figure 3 showed the results obtained for the soil pH values. Overall the zones presented acidic pH values for the soils (fig. 3). In autumn, the range of values vary between 3.96 and 4.77 at zones B and A, respectively, and in spring samples values varied between 4.28 at zone C and 4.97 at zone A.

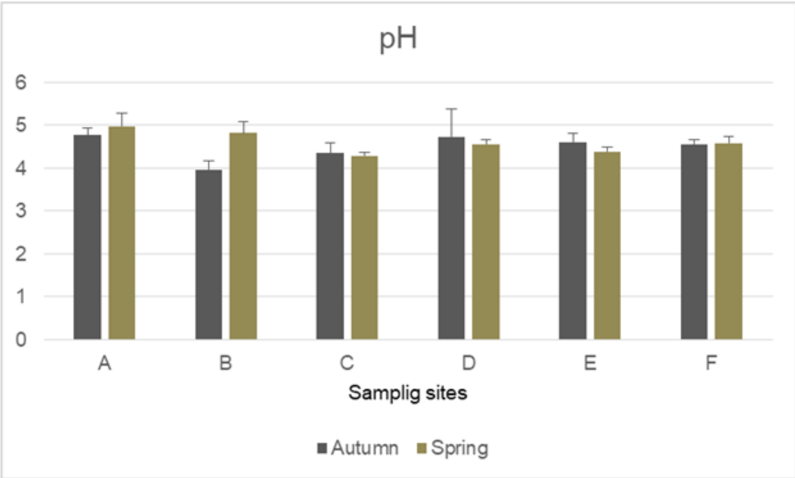


Figure 3 - Results of pH values (mean + standard deviation) for each sampling zone and for the two sampling campaigns (autumn and spring)

Conductivity values (fig. 4) presented variations between seasons and zones. The range of the conductivity values in spring season were similar with small variations, while in autumn the highest differences were recorded between sites. On autumn, the lowest value was measured at zone A (37.33 µS/cm) and the highest values on zone C (151.48 µS/cm). However, the latter showed a high standard deviation due to the differences in the values amongst the four replicates. In opposite, zone C in spring season presented one of the lowest value recorded (27.98 µS/cm) similar to the observed in zone A (27.19 µS/cm). The highest value on spring was registered at zone F (85.65 µS/cm).

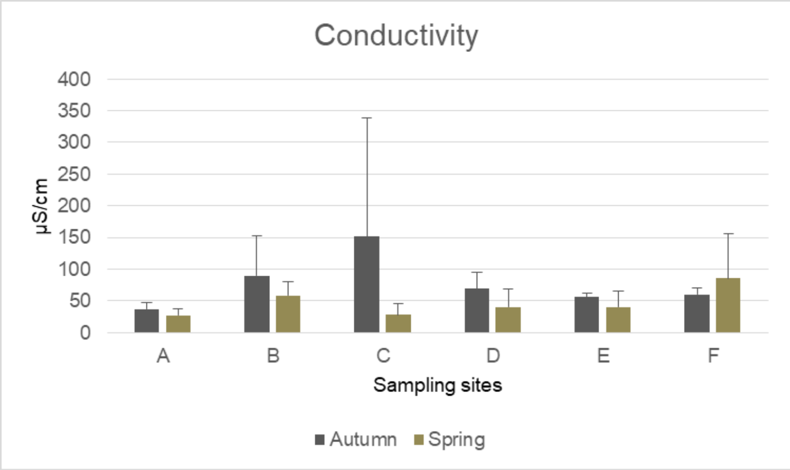


Figure 4 - Results of conductivity values (mean + standard deviation) for each sampling zone and for the two sampling campaigns (autumn and spring)

Figure 5 exhibits the water holding (WHC) capacity values measured in soil samples. In C, E, and F sites the values observed were higher on spring than in autumn. The lowest WHC percentage occurred at E site during autumn (22.46%) and the highest WHC value was observed in site C during the spring season (65.07%).

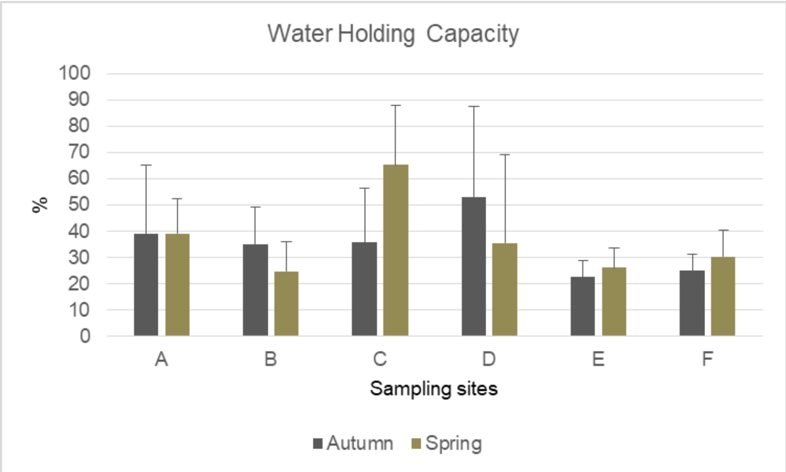


Figure 5 - Results of water holding capacity percentage (mean + standard deviation) for each sampling zone and for the two sampling campaigns (autumn and spring)

Organic matter (OM) content presents a range between 17.73% at zone A and 31.73% at zone E, both in spring season (fig. 6). The sites where were recorded te highest values of OM were the site B in the autumn season and the site E in spring. According to Rusco et al. (2001) all the studied soils are considered to present a high organic content since all values are up 6%.

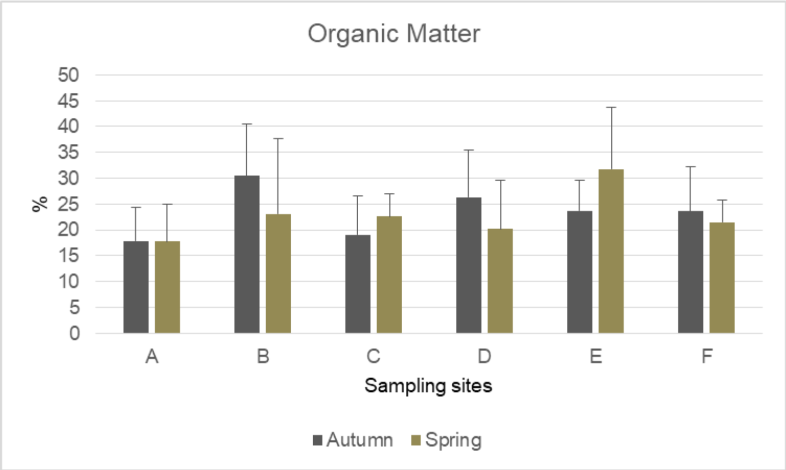


Figure 6 - Results of organic matter percentage (mean + standard deviation) for each sampling zone and for the two sampling campaigns (autumn and spring)

Vegetation characterization

The study area is actually characterized by a low species richness (table 2), where only 10 different taxa were identifyed in all sampling zones. Zone A presented the lowest cover percentage in both seasons (35% for autumn and 55% for spring) while zone E presented the highest. In general, the zones where older *Eucalyptus* sp. is present (E and F) were the zones with highest diversity and more understory coverage. Zone E also exhibit the highest shrub cover in the study area, namely with the presence of *Calluna vulgaris, Pterospartum tridentatum, Ulex minor, Cytisus striatus* and *Erica* sp. *Helianthemum* sp. only appeared at zone C and *Agrostis* sp. appeared only at zone E and was the only herbaceous taxa observed in all the study sites. Zone F is characterized by the presence of *Hakea sericea*, an exotic shrub or small tree with origin in Australia (Paiva, 1989). This species occurs as spontaneous in Portuguese territory (Flora.on) and is considered highly invasive according to the Portuguese law (Dec. Lei nº 565/99 de 21 de Dezembro; Invasoras, 2014b).

Table 2 - List of vegetation species and correspondent coverage percentage for each sampled zone and by season

	A		B		C		D		E		F	
	Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr
Eucalyptus globulus	0	20	50	50	0	0	40	60	80	80	20	25
Calluna vulgaris	25	25	0	0	10	10	5	5	15	15	5	20
Pterospartum tridentatum	10	10	10	10	60	60	5	5	20	20	5	5
Pteridium aquilinum	0	0	8	8	0	0	0	0	0	0	0	0
Ulex minor	0	0	0	0	5	5	0	0	5	5	0	0
Cytisus striatus	0	0	0	0	0	0	0	0	30	30	15	15
Helianthemum sp.	0	0	0	0	0	10	0	0	0	0	0	0
Erica sp.	0	0	0	0	0	0	0	0	5	5	0	0
Agrostis sp.	0	0	0	0	0	0	0	0	5	5	0	0
Hakea sericea	0	0	0	0	0	0	0	0	0	0	60	60
Richness	2	3	3	3	3	4	3	3	7	7	5	5
Total cover percentage	35	55	68	68	75	85	50	70	160	160	105	125

Soil seed bank

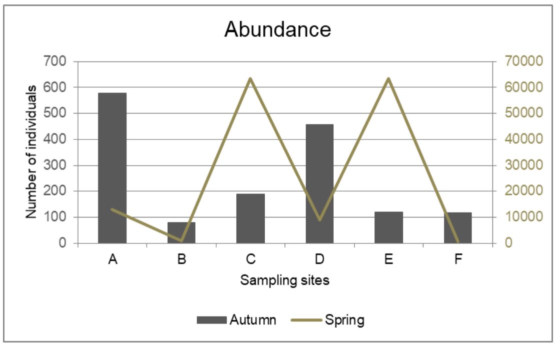
The seed germination from the soil samples was followed over 7 months (November 2017 to May 2018). Along this period some seed germination was observed (table 3). No matter how the seedling never developed enough to be conducted a taxonomic identification of the individuals. However, the zones with more germinations recorded were coincident with the zones with lower presence of *Eucalyptus* sp. cover (zones A and C).

Table 3 - Number of seeds germinations in each zone of the study area

Zones	N.º of germinations
A	15
B	2
C	19
D	3
E	8
F	3

Arthropods community

The total number of edaphic individuals identified were 151885, 1541 in autumn and 150344 in spring. spring abundance was much higher at all the zones besides zone F (autumn – 117 individuals, spring – 526 individuals) (fig. 7). These results are due to the high number of Collembola individuals of the families Entomobryidae and Hypogastruridae (table A1 in annex). Moreover, collembola was the most represented class in the two sampling period (55.22% - autumn and 96.40% - spring).These organisms abundance increased in the zones where the organic matter and water holding capacity also increased, namely in spring season. Regarding richness values, in autumn season, 50 families were identified distributed for 13 orders, whyle in the spring season the number increase to 67 families distributed for 20 orders (*see*, table A1 in annex). Zone C presented the lowest number of *taxa* in autumn (10) and zone B presented the highest richness observed on spring (40) (fig.7). The number of taxa per season was substantially different, with zone C presenting the highest difference and zone F the lowest difference among seasons.



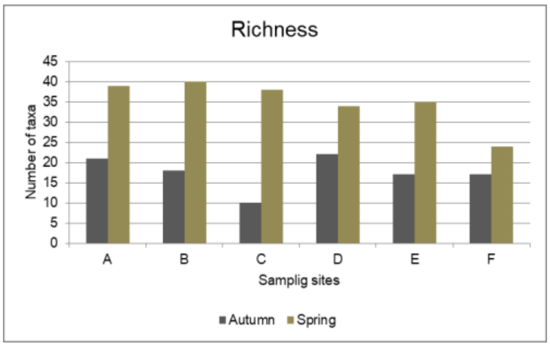


Figure 7 - Variation of abundance (left) and richness (right) values in each sampling zone for autumn and spring campaigns

Shannon-Wiener and Pielou evenness indexes were calculated to access the diversity and the equitability of the edaphic fauna in the sampling area (fig. 8). Diversity values range between 0.35 (zone E on spring) and 1.91 (F on autumn). In most of the zones (exception for the zone B) the diversity values were higher in autumn season. The highest difference of the values among the seasons were recorded in zone E, while zone F showed a slight variation of diversity between the two sampling seasons.

Regarding the results of Pielou evenness index (fig. 8), zone E shows the lowest value of evenness (J'=0.12) on spring and zone F presents the highest values recorded (J'=0.89) on autumn. The differences in the indexes results between seasons are mostly explained by the increasing of Springtails organisms, particularly from the family Hypogastruridae. It is possible to observe a certain trend among the two graphics, high diversity values corresponds to high equitability values. This means that the number of organisms is balanced in each zone and that there is no dominant species in the distribution. On the other hand, when both numbers are low it is to predicted that there is a dominance of some organisms. Zone F is a good example of a balanced distribution in both seasons and zone E on spring is an example of an imbalanced distribution.

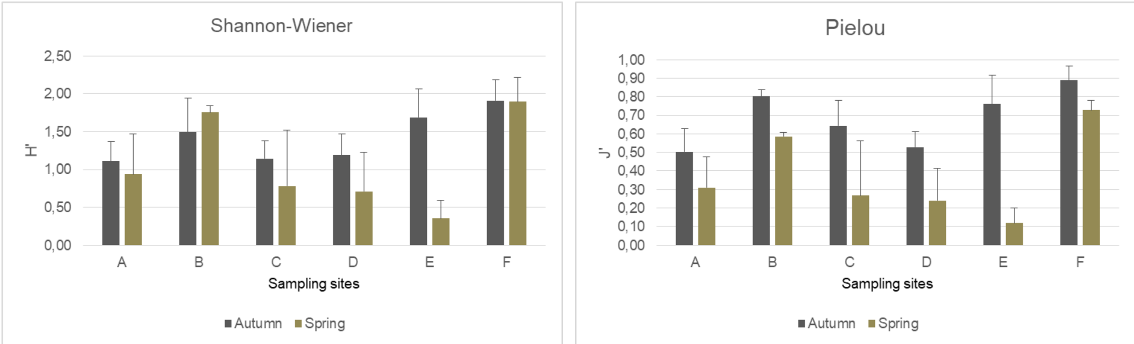


Figure 8 - Variation of Shannon diversity (left) and Pielou evenness (right) indexes (mean + standard deviation) at each sampling zone for autumn and spring campaigns

To perceive the relation between the community of edaphic arthropods and the sampling zones two Detrended Correspondence Analysis (DCA) were performed, one for autumn (fig. 9) and the other for spring (fig. 10) (see abreviations of table 2 in Annex). The graphics figures showed different sampling sites and *taxa* distribution on autumn and spring season. Though axis 1 and axis 2 explain 27.1% data variance on autumn and 47.1% on spring it is not possible to associate any organisms to any of the locations. It is likely that the identified *taxa* is composed with more generalist families able to adapt under a variaty of circumstances. The surroundings of the study area are mostly an uniformed landscape of *Eucalyptus* sp. with low diversity of vegetation not supporting specific fauna organisms, which might contribute to these results.

On autumn the set of samples close to axis 2 is composed essentially by the replicates of the sites with lower *Eucalyptus* sp. presence, A and C, and replicates of zone D. Despite having a higher *Eucalyptus* sp. coverage than the other sites, this presence is basically composed by sprout shoots from the logging that happened some months before the sampling period. Replicates B2, B3 and B4 form another set. Regardless been near the previous set, the reason to be apart from it might be due to the presence of grown *Eucalyptus* sp. trees. Replicates of the zones E and F are close to each other and have in common the presence of grown *Eucalyptus* sp. trees and a more diverse understory cover.

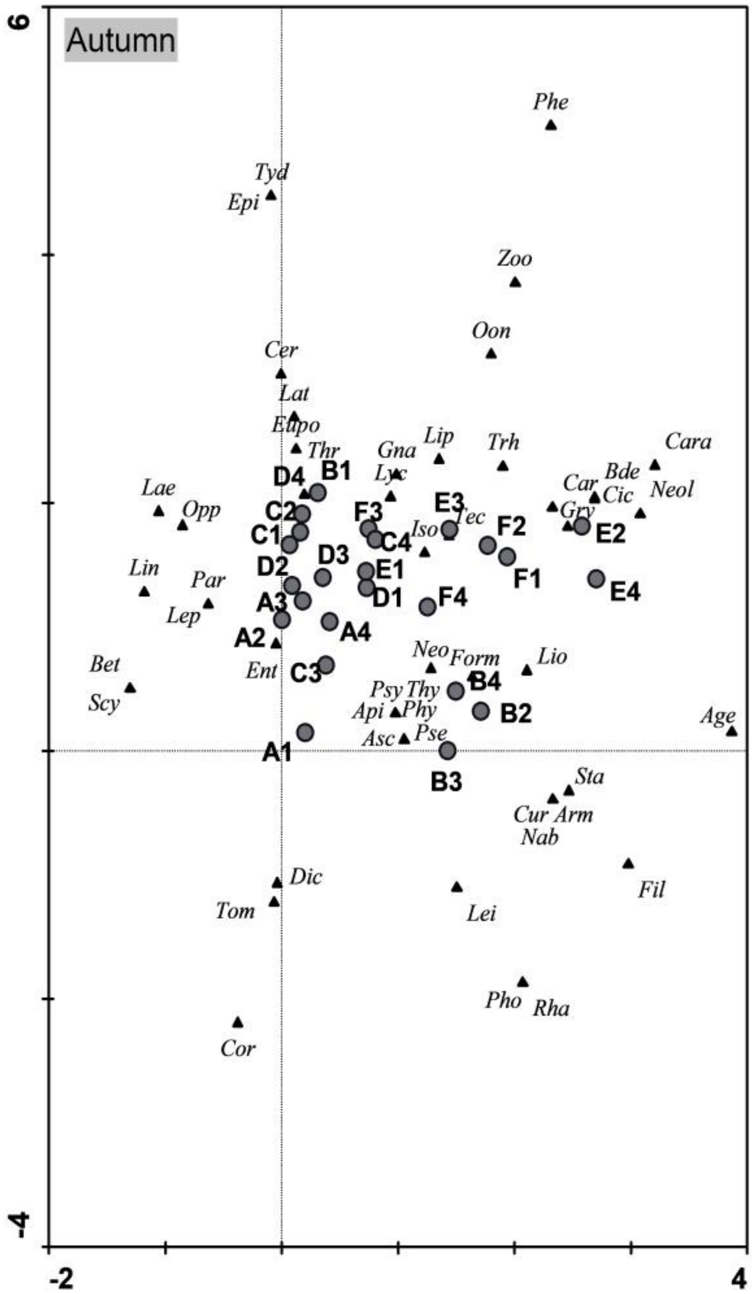


Figure 9 - Graphical representation of autumn DCA using edaphic family's composition and zone replicate following the nomenclature on Table II in Annex

On spring the distribution of the replicate samples were totally different from the autumn period. One of the most influence elements seem to be the abundance of the organisms. Besides A3 and D3 replicate, the set of overlapping dots in the right corner of the graphic have all thousands of organisms. Besides C1 and C2 replicates, all the others follow a horizontal position in the study area (fig. 2) and they all, including C1 and C2, are the edge of the study area. The other group possible to identify is that vertical alignment composed by the F zone replicates and B3 and B4. Their abundance is also similar ranging between a hundred organisms in F1 and 311 in B3.

The differences of the organisms distributions through the seasons can be related to the climate differences. 2017 was an exceptional year due to its hot temperatures and drought situation (IPMA, 2017) that determinated anusual climate characteristics for a northern Portugal autumn

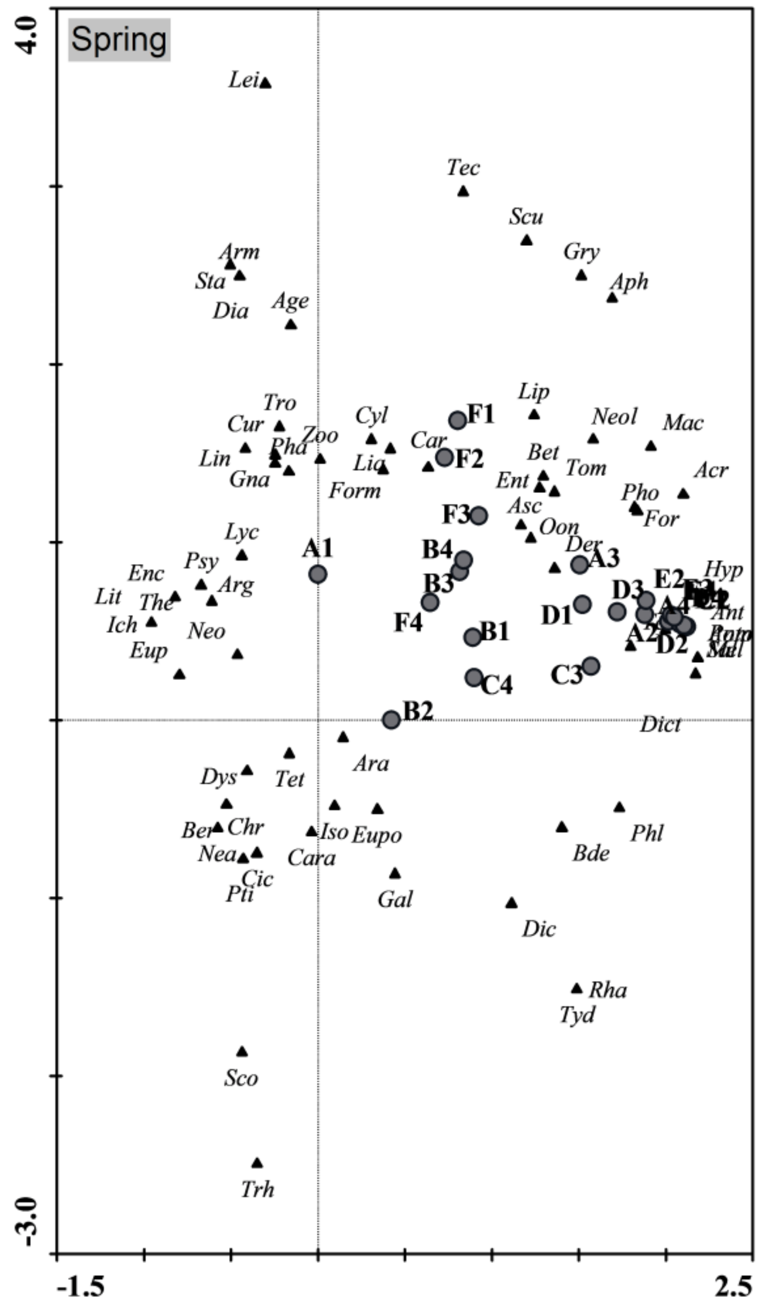


Figure 10 - Graphical representation of spring DCA (right) using edaphic families composition and zone replicate following the nomenclature on Table II in Annex

Discussion

In the last 70 years, farming *Eucalyptus* sp., especially *Eucalyptus globulus,* in Portugal, became common and has increased until nowadays, situation on which their presence became the highest in forest coverage percentage of the country. However, this process was characterized by significant changes in topography, landscape soil and biological communities (Alves et al., 2007; Fabião et al., 2007; Onofre, 2007; Reboredo and Pais, 2014). Thus, characterizing these new systems can help to understand these changes and the real impacts of the introduction of *Eucalyptus* sp. in the forest areas. According to these concerns, this study worked to assess the differences in soil physical and chemical properties and identification of understory vegetation, as well as the alterations of the edaphic community in different vegetation covers in a *Eucalyptus* sp area.

According to *Soil Atlas of Europe* (European Commission, 2005), Portugal northern region presents Umbrisoils, characterized by an acidity and rich organic matter horizon. The analysed soil samples presented acidic pH values for both seasons, ranging between 3.96 and 4.97 (fig. 3) being in accordance to the type of soil of the northern region. Some studies associate *Eucalyptus* sp. plantations shown a decrease of soil pH values due to the remove of logging litter and consequent exportation of nutrients from the fields (Madeira et al., 2007; Faria et al., 2009; Madeira, 2015). However, a lack of information about soil pH before the plantation processes do not allowed to assess the direct impact of this species to soil pH current values.

Electrical conductivity here-obtained results are similar to presented in other studies carried out in *Eucalyptus globulus* plots at other Iberian areas, namely in Arouca (Pereira et al., 2014) and Galicia, Spain (Barreiro et al., 2015), under Umbrisoil features (European Commision, 2005). Conductivity measures the ability of the soil to conduct electricity and can be used to express the salinity values (Bunning et al., 2016). Zone C showed an high difference in conductivity values between seasons, suggesting a large accumulation of salts in soil, namely in autumn. This differences may be due to soil substances leaching by the winter and spring rains (Bunning et al., 2016).

Water holding capacity and organic matter content seemed to follow the same pattern when seasons are compared. In fact WHC is related to the content of the OM content, when the soil has high values of OM an increase of the soil to uptake the water was observed (Antunes et al., 2009; Santos, 2017). However, it was also expected that the zones presenting higher OM values also presented higher WHC values, which is not observed in our results. That might be caused by the percentage and type of vegetation cover recorded (table 2). Zones with more *Eucalyptus* sp. coverage percentage (B, E and F – table 2) have a higher content of OM (figure 6), however, those are exactly the zones with lower WHC values (figure 5). This is probably connected to soil hydrophobicity. In 1996, Doerr et al. compared *Eucalyptus globulus* and *Pinus pinaster* plantations in Portugal and associated a higher lack of water absorption to *Eucalyptus* sp. plot. Moreover, when hydrophobic soil samples of both species were submerged, the *Pinus* sp. soil sample immediately soaked while for *Eucalyptus* sp. soil samples took several hours. De Blas et al. (2013) studied *Eucalyptus* sp. areas at Galicia and under similar soil conditions as the present study, attributed soil hydrophobicity to *Eucalyptus* sp. leaves lipids composition, specially monoterpens. So, the amount of *Eucalyptus* sp. remains in the organic soil layer may influence soil water absorption. In zones B, E and F, *Eucalyptus* sp. trees remains are supposed to be the main contributors to the soil organic layer formation as this species has the higher vegetation coverage percentages in those zones and so may be the main reason for the lower WHC values. On the other hand, several authors demonstrate that dry soils tend to have less water absorption capacity due to the accumulation of hydrophobic substances (DeBano, 1981; Doerr et al., 1996; Doerr et al., 2000; Ferreira et al., 2000). Indeed, autumn soil samples were collected before the first rains, still in the severe drought season that the country was facing due to the exceptional climatic conditions of 2017 (IPMA, 2017). This might have influenced the soil water absorption capacity explaining the differences on WHC values between autumn and spring samples, since spring sampling period was performed after rainy periods (IPMA, 2018a, 2018b).

Understory coverage is represented by a low vegetation diversity in all sampling zones. *Erica* sp., *Ulex* sp. and *Calluna vulgaris* are the common species under *Eucalyptus* sp. plantations in the northwest of the Iberian Peninsula and under the same edapho-climatic conditions of the present study (Basanta et al., 1989; Fernández et al., 2004; Teixido et al., 2010). Fabião et al. (2007), Basanta et al. (1989) and Proença et al., (2010) added *Agrostis* sp., *Cytisus* sp. and *Erica* sp. to the previous cited species as pioneers after the occurrence of disturbances at terrestrial ecosystems (namely, after trees logging, in agriculture lands' transition to forest and after fires). Considering common managing *Eucalyptus* sp. crop practices with a short rotation periods (Madeira, 2015; Soares et al., 2007) it is assumed that all the study area is in an ecological succession process. However, different stages of the process are observed. From areas recently intervened (A and D), areas with young *Eucalyptus* sp. trees (B and C – at the surroundings) or areas with mature trees (E and F), a certain tendency of plant diversity increasing is observed with the maturity of the trees. Moreover, Carneiro et al. (2008) and Fabião et al. (2007) already described understory diversity losses related to the crops harvesting procedures and their recovery with maturity.

The presence of the invasive species *Hakea sericea* at zone F seems not to interfere in the ecosystem vegetation cover richness but only in its abundance. This shrub, native from southern Australia (Invasoras.pt, 2014b) has been recognised has highly invasive and competitive against other vegetation species (van Wilgen and Richardson, 1985; Tucker and Richardson, 1995; Ducatillion et al., 2015). The aptitude to create great density stands (Invasoras.pt, 2014b), high amounts of long-lived and seeds and an enhanced nutrient and water uptake promotes *H. sericea* competition advantage (Sousa, 2009), probably explaining vegetation coverage percentages of zone F.

Regarding to soil seed germinations seems to be linked to the presence or absence of *Eucalyptus* sp. (table 3). Allelopathy phenomenon has been associated to *Eucalyptus* sp. with a reduction in seed germinations and the seedling growth of other vegetation species (Souto et al., 1994; Valente, 2015; Puig et al., 2018). Indeed, some bioassays have been conducted to explore *Eucalyptus globulus* extracts in agriculture weed controller with high level of success in the results (Puig et al., 2013; 2018; Rassaeifar et al., 2013). The high concentration of several substances on the leaves and exudates of *Eucalyptus globulus*, as phenolic compounds and terpenoids, proven to be phytotoxic, grant allelopathic aggressiveness from *E. globulus* against other species (Molina et al., 1991). This phenomenon and the presence of *Eucalyptus globulus* (dominant species in some of the studied zones) may explain the differences in the numbers of the seed germination experience, even if the differences in the number of germinations may not be significant. Furthermore, allelopathic substances may persist for several months on soil (May and Ash, 1990) but without a continuous provision promoted by exudates and litter material from the trees, the phytotoxic features may lose their effect through the decaying of their properties along time (Mandava, 1985; de Blas et al., 2013). Zones A and D might be an example of this effect. In both areas, *Eucalyptus* sp. trees had been reduced to sprouts several months before the autumn sampling period. At zone A, trees had a slower growth comparing to zone D as other *in situ* assay was conducted by another team. Allelopathic effect at zone A may have been moderated by the lack of provision of *Eucalytpus* sp. litter allowing more seeds germination. In any case, the previous explanations should be taken with caution since the number of seed germinations is not representative to guarantee cause-and-effect relations.

Edaphic arthropods communities are influenced by soil's physical and chemical features since these parameters can dictate water presence, mineral composition and acid-base equilibrium (Jeffery et al., 2010). Besides, the presence or the lack of vegetation cover, composition and structure determines the presence and the complexity of the fauna due to the purveyance of food, shelter and shade (Swarts, 2006; Schaffers et al., 2008; Jeffery et al., 2010). Regarding our results, the arthropod community suffered huge changes from autumn to spring, in all sampling zones (fig. 7). On both seasons, highest abundances seem to be related to the zones where a conjugated increase of OM and WHC values occur (A and D on autumn and C and E on spring). The importance of these physical and chemical parameters have already been described as relevant for edaphic arthropods dynamics (Verhoef and van Selm, 1983; Scheu and Schulz, 1996; Rodrigues, 2004; Reis et al., 2012; Nsabimana, 2013; Reis, 2014; Bagyaraj et al., 2016) stimulating its growth. Zones A and D also have disturbance as a common feature as the *Eucalyptus* sp. trees were cut. Indeed, several studies have been searching to understand invertebrates' reaction to intensive disturbances and how the affected areas are recolonized (Neumann, 1991; Yi and Andrew, 2008; Antunes et al., 2009; Higgins et al., 2014). Usually, after a radical environmental change (e.g. fire, thinning, tillage) the affected areas become recolonized by opportunists' species that by the little number of predators are able to reproduce intensively. Ants and Collembola are among those groups as some mites as Eupodidae family as their feeding habits are essential omnivorous and decomposers (Adolphson and Kinnear, 2008; Antunes et al., 2009; Serralheiro and Madeira, 2014). Predators' abundance was much lighter at those zones as they need the preys to be established to feed on them. Disturbance might have been the propellant factor for the higher edaphic organisms' abundances at zones A and D on autumn comparing to the other zones of the study site. Despite that, abundance increasing did not reflected discrepancies among zones richness values (fig. 7) as it could have been expected by the possible dominance of some families.

The differences in arthropods community composition is usually related to seasonality changes of climatic factors, such as temperature, precipitation and day length (Arnaldos et al., 2004; Simão et al., 2015). In spring the organisms' abundances were always higher comparing to autumn season due to the increase numbers of decomposers organisms, namely springtails and oribatid. Although this organisms are intimately related to high values of OM content (Santos, 2017), in this study it is probable that seasonality played an important role as most of the zones presented lower OM values comparing to autumn sampling period. At zones C and E, where OM and WHC increased, the abundance of organisms also increases in about 500 times more, specially due to Hypogastruridae family. Several studies have demonstrated that springtails and oribatid mites are especially sensitive to soil moisture content (Verhoef and van Selm, 1983; Caballero, 2011; Parwez and Sharma, 2014). Villani (1999) and Serralheiro and Madeira (2014) describe edaphic arthropods strategies according to their environment adaptations and refer that these organisms can migrate to deep soil layers as a defensive measure, seeking lower temperatures and higher moisture concentrations. The year of 2017 was characterized as extreme hot with a prolonged drought situation, until November, in Portugal (IPMA, 2017). As the autumn sampling period was in November, this might had influenced arthropods survival strategies. Also, the possible concentration of *Eucalyptus* sp. allelopathic substances on soil during this excessive dry season may have affect the abundances as it is proven that can be harmful to the edaphic invertebrates (Mandava, 1985; Martins et al., 2013; Calviño-Cancela et al., 2012). Normally, spring season was characterized by an enrichment of edaphic predators' abundance. The number of spiders was considerably higher, and high abundance of predators, as beetles, centipedes and opiliones, is recorded in this season. An expected result as an increase of preys abundance tends to lead to an increase in predators' abundance (Cardoso et al., 2007). Also, Insecta class improved its richness as most of the Hymenoptera identified *taxa* are only present on spring (table I in annex).

Vegetation coverage percentage did not improve (Zones B, C and E) from autumn to spring or kept a slight growth (A, D and F), and only one new *taxa* appeared on spring at zone C (*Helianthemum* sp.). As so, the vegetation abundance do not seem to have significant influence on the arthropods abundance as some studies suggest (Ratsirarson et al., 2002; Randlkofer et al., 2010). The area of the present study is composed with a diverse vegetation matrix with a mix of disturbed areas, grown and young *Eucalyptus globulus* trees. Zone A and C (fig. 2) are boundary area and are located close to zone E which constitutes the limit of a more mature crop zone. Vegetation transition limits are important spaces to the maintenance of complex and diverse ecosystems matrix and have been referenced as important shelters for fauna (Altieri and Schmidt, 1986; Antunes et al., 2009; Simão et al., 2015). According to this, it is considered possible that organisms from zone E have migrated to zone A being the first zone a stock for edaphic fauna, explaining the high numbers of springtails presented on spring and the high richness values. Zone C had as east limit mixed *Eucalyptus* sp. with oak trees areas and an area similar to zone E to the north. Although none of the zones outside the limit were studied, the same transition effect might have contributed to the high abundance and richness of zone C.

Zone F is the only zone with the high abundance of an invasive species, *Hakea sericea*. This zone presented the lowest edaphic abundances and richness, for both seasons. However, no studies were found connecting *H. sericea* species to diversity and abundance of edaphic arthropods. Nevertheless, other studies have reported the process of invasion by alien species with the decrease of diversity in flora and fauna of the invaded ecosystems (Procheş et al., 2008; Heleno et al., 2009; Litt et al., 2014). During autumn sampling the abundance of all the *taxa* (zone F) was low but there seems to exist a balance between preys and predators. During spring, Formicidae was the only represented *taxa* of Hymenoptera order, Aphididae and Psyllidae the only families recorded in Hemiptera, and Coleoptera order is represented by Curculionidae and Leiodidae (table I in annex). Comparing zones E and F, both with mature *Eucalyptus* sp. trees, zone F lacks herbaceous and shrub, probably due to *H. sericea* competing presence (van Wilgen and Richardson, 1985) and that could have influenced the diversity of invertebrates community. But even if the abundances were totally different, zone F seem to have the same *taxa* has zone E which make to doubt about *H. sericea* impact on the arthropods or if that was caused by the joint effect of both invasive *H. sericea* and *Eucalyptus globulus*.

Eucalyptus sp. plantations have been classified as low diversity ecosystems (Zhang and Fu, 2010; Calviño-Cancela et al., 2012; Serralheiro and Madeira, 2014; Madeira, 2015; Valente, 2015). Despite the presence of an alien species, and its exploitation in monoculture systems where the managing practices imply direct hard effects on soil physical and chemical properties and understory community (Fabião et al., 2007; Madeira et al., 2007; Carneiro et al., 2008; Calviño-Cancela et al., 2012; Serralheiro and Madeira, 2014) significant effects in arthropods community were already documented. Sousa et al. (2000), in a review about Collembola *taxa,* compared *Pinus* spp. and other species (*Quercus* sp., *Castanea sativa* Mill. and other broadleaved trees ecosystems) to *Eucalyptus globulus* plantations and concluded that the exotic species promoted an impoverishment and disruption of the Collembola communities. Antunes et al. (2008), Calviño-Cancela et al. (2012), Pereira et al. (2014) and Valente (2015) elaborated similar studies and concluded that *Eucalyptus* sp. introduced significant changes in soil properties, fauna and flora communities. In addition, the presence of exotic invertebrate fauna with origin, essentially, in Australia in *PSeP* have already been reported (Hemiptera: *Ctenarytaina eucalypti, Ctenarytaina spatulata;* Hymenoptera: *Anaphes nitens, Psyllaephagus pilosus, Ophelimus* sp.; Coleoptera: *Gonipterus platensis*) (Carlos Valente – The Navigator Company, 2018, personal communication). However, the edaphic arthropods taxonomic identification of this study was only performed until family not allowing to know if some of the identified organisms were native or exotic. These organisms may contribute to higher values of abundance and richness in *Eucalyptus* sp. plots, however the impacts of these organisms are only assessed on *Eucalyptus* sp. trees and not on the remaining biotic communities, and their possible contribution to native invertebrate species loss is not yet understand.

One important result observed is the outcome of the DCA's analysis where no specific relation between the *taxa* and the site samples were observed. One reason for that situation could be related to the possible surrogacy of specialist arthropods for generalist ones (Ratsirarson et al., 2002; Scheu and Schulz, 1996), namely, Carabidae, Tenebrionidae, Melyridae, Ascidae, most of the spiders and the presence of cosmopolitan *taxa* as most of the oribatid mites and springtails (Santos, 2017) due to the lack of heterogeneity understory cover. This testifies the need for long term studies comparing young *Eucalyptus* sp. plantations to mature ones analysing the evolution of the understory coverage and arthropod communities so the dynamic and complexity of this type of ecosystem can be assessed (Calviño-Cancela et al., 2012). Also, the scientific results from these researches can assist authorities for the creation of better forest plan management to prevent huge diversity losses as the consequences of monocultures influence on native ecosystems are understand.

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Annex

Tabela I - Designation of all the taxa identified with their abundance and distribution among the study zones. Purple indicates the taxa which appeared in all the zones and pink indicates the ones which appeared only in one zone (taxonomic identification according to Zhang, 2011)

			Autumn						Spring					
Class	**Orders**	**Families**	**A**	**B**	**C**	**D**	**E**	**F**	**A**	**B**	**C**	**D**	**E**	**F**
Collembola	Entomobryomorpha	Entomobryidae	390	10	41	209	20	18	396	313	308	234	1129	151
		Isotomidae	19	-	47	55	3	14	-	17	24	-	-	-
		Tomoceridae	20	2	1	-	-	-	34	17	32	4	36	20
	Poduromorpha	Hypogastruridae	-	-	-	-	-	-	10517	61	62165	8435	60940	21
		Neanuridae	-	-	-	-	-	-	2	1	-	-	-	-
	Symphypleona	Dicyrtomidae	2	-	-	-	-	-	6	5	56	3	3	7
Insecta	Archaeognatha	Machilidae	-	-	-	-	-	-	2	-	1	1	12	-
	Coleoptera	Anthribidae	-	-	-	-	-	-	1	-	-	-	-	-
		Apionidae	-	-	-	1	-	-	-	-	-	-	-	-
		Carabidae (larvae)	-	-	-	-	-	-	-	-	-	-	2	-
		Carabidae	1	-	-	3	4	3	1	1	1	-	3	-
		Chrysomelidae	-	-	-	-	-	-	-	1	-	-	-	-
		Corylophidae	1	-	-	-	-	-	-	-	-	-	-	-
		Curculionidae	-	1	-	-	-	-	-	3	-	-	-	2
		Latridiidae	1	1	-	-	-	-	-	-	-	-	-	-
		Leiodidae	2	6	2	2	-	-	-	4	1	-	4	11
		Melyridae	-	-	-	-	-	-	-	-	3	-	-	-
		Ptiliidae	-	-	-	-	-	-	-	2	-	-	-	-
		Scolytidae	-	-	-	-	-	-	-	4	-	-	-	-
		Scydmaenidae	1	-	-	-	-	-	-	-	-	-	-	-
		Staphylinidae	-	4	-	-	2	-	5	6	-	1	2	4
		Tenebrionidae	-	-	-	-	-	-	1	-	-	-	-	-
	Dermaptera	Forficulidae	-	-	-	-	-	-	1	-	-	1	2	-
	Hemiptera	Anthocoridae	-	-	-	-	-	-	-	-	1	-	-	-
		Aphididae	-	-	-	-	-	-	1	-	1	-	1	1
		Berytidae	-	-	-	-	-	-	-	1	-	-	-	-
		Cercopidae (nymph)	-	-	1	-	-	-	-	-	-	-	-	-
		Cercopidae	-	-	-	1	-	-	-	-	-	-	-	-
		Cicadellidae (nymph)	-	-	-	-	-	-	1	-	3	-	1	-
		Cicadellidae	-	-	-	1	1	-	-	-	-	-	-	-
		Dictyopharidae (nymph)	-	-	-	-	-	-	-	-	-	1	-	-
		Nabiidae	-	1	-	-	-	-	-	-	-	-	-	-
		Pseudococcidae (nymphs)	-	-	4	-	-	2	-	-	-	-	-	-
		Psyllidae (nymph)	-	-	-	-	-	-	37	3	2	14	3	-
		Psyllidae	-	-	-	6	-	-	18	1	2	4	-	1
	Hymenoptera	larvae	-	-	-	-	-	-	-	-	1	2	-	-
		Bethylidae	1	-	-	-	-	-	-	2	-	2	2	-
		Diapriidae	-	-	-	-	-	-	-	2	-	-	-	-

		Encyrtidae	-	-	-	-	-	-	945	13	2	142	5	-
		Eupelmidae	-	-	-	-	-	-	5	1	-	1	-	-
		Ichneumonidae	-	-	-	-	-	-	2	-	-	-	-	-
		Formicidae	40	27	3	8	13	29	24	10	33	10	10	32
		Pompilidae	-	-	-	-	-	-	-	-	1	-	-	-
	Orthoptera	Acrididae	-	-	-	-	-	-	-	-	-	-	1	-
		Gryllidae	2	1	-	-	4	1	-	-	-	1	1	1
	Psocoptera	Lepidopsocidae	1	-	-	-	-	-	-	-	-	-	-	-
		Liposcelidae	1	-	-	2	-	1	-	-	-	1	-	-
		Trogiidae	-	-	-	-	-	-	-	-	-	2	-	-
	Thysanoptera	Phlaeothripidae (nymph)	-	-	-	-	-	-	3	2	31	-	10	-
		Thripidae	-	-	-	2	-	-	-	-	-	-	-	-
Arachnida	Araneae	juvenile	-	-	-	-	-	1	9	6	-	3	1	-
		Agelenidae	-	-	-	-	1	-	7	6	1	11	3	5
		Araneidae	-	-	-	-	-	-	-	1	-	1	-	-
		Dysderidae	-	-	-	-	-	-	-	1	1	-	-	-
		Filistatidae	-	1	-	-	1	-	-	-	-	-	-	-
		Gnaphosidae	-	-	-	1	-	1	4	3	2	5	2	2
		Linyphiidae	1	-	-	1	-	-	4	10	4	1	8	3
		Liocranidae	3	4	-	1	-	9	-	-	-	-	-	-
		Lycosidae	1	-	-	1	1	-	1	-	1	2	-	-
		Oonopidae	-	-	1	-	-	1	-	1	2	7	2	1
		Pholcidae	-	1	-	-	-	-	-	-	-	3	-	-
		Salticidae	-	-	-	-	-	-	-	-	1	-	-	-
		Theridiidae	-	-	-	-	-	-	1	-	-	-	-	-
		Zoodariidae	-	-	-	-	1	1	-	2	1	-	2	2
	Mite	Not identified	-	-	-	-	-	1	1	-	-	7	-	-
	Ixodida	Argasidae	-	-	-	-	-	-	2	-	-	-	2	-
	Mesostigma	Ascidae	-	-	-	1	-	-	3	5	3	1	1	-
		Dermanyssidae	-	-	-	-	-	-	5	4	11	12	9	-
		Epicriidae	-	2	-	-	-	-	-	-	-	-	-	-
		Laelapidae	-	-	-	1	-	-	-	-	-	-	-	-
		Parasitidae	1	-	-	-	-	-	-	-	-	-	-	-
		Phytoseiidae	-	-	-	1	-	-	-	-	-	-	-	-
	Trombidiformes	Bdellidae	-	-	-	-	6	2	1	-	21	-	3	2
		Carabodidae	-	-	-	-	4	2	2	12	28	2	1	5
		Eupodidae	85	15	87	147	20	13	149	264	637	55	128	82
		Galumnidae	-	-	-	-	-	-	-	2	-	2	-	-
		Liacaridae	-	-	-	-	-	-	774	55	31	20	1091	117
		Neoliodidae	-	-	-	8	37	14	4	2	1	7	14	6
		Oppiidae	4	1	3	-	-	-	-	-	-	-	-	-
		Phenopelopidae	-	-	-	-	1	-	-	-	-	-	-	-
		Rhagidiidae	-	1	-	-	-	-	-	-	4	-	-	-
		Tectocepheidae	-	-	-	3	-	3	3	11	16	8	49	44
		Tetranychidae	-	-	-	-	-	-	8	6	11	7	10	5
		Thyrisomidae	-	-	-	1	-	-	-	-	-	-	-	-

		Trhypochthoniidae	-	-	-	-	-	1	-	-	-	-	-	-
		Tydeidae	-	1	-	-	-	-	-	-	10	-	-	-
	Pseudoscorpiones	Neobisiidae	1	-		-	1	-	3	1	2	-	-	1
	Opiliones	Phalangiidae	-	-		-	-	-	1	-	1	1	3	-
Malacostraca	Isopoda	Armadillidiidae	-	1		-	-	-	-	1	-	-	-	-
		Cylisticidae	-	-		-	-	-	-	1	-	-	1	-
Chilopoda	Lithobiomorpha	Lithobiidae	-	-		-	-	-	1	-	-	-	-	-
	Scutigeromorpha	Scutigeridae	-	-		-	-	-	1	-	-	-	-	-

Tabela II - Abbreviation of the name of all the taxa used in DCA's graphics

Taxa	Abbr.	Taxa	Abb.	Taxa	Abb.	Taxa	Abb.
Acrididae	Acr	Dicyrtomidae	Dic	Liocranidae	Lio	Salticidae	Sal
Agelenidae	Age	Dictyopharidae	Dict	Liposcelidae	Lip	Scolytidae	Sco
Anthribidae	Ant	Dysderidae	Dys	Lithobiidae	Lit	Scutigeridae	Scu
Anthocoridae	Anto	Encyrtidae	Enc	Lycosidae	Lyc	Scydmaenidae	Scy
Aphididae	Aph	Entomobriydae	Ent	Machilidae	Mac	Staphylinidae	Sta
Apionidae	Api	Epicriidae	Epi	Melyridae	Mel	Tectocepheidae	Tec
Araneidae	Ara	Eupelmidae	Eup	Nabiidae	Nab	Tenebrionidae	Ten
Argasidae	Arg	Eupodidae	Eupo	Neanuridae	Nea	Tetranychidae	Tet
Armadillidiidae	Arm	Filistatidae	Fil	Neobisiidae	Neo	Theridiidae	The
Ascidae	Asc	Forficulidae	For	Neoliodidae	Neol	Thripidae	Thr
Bdellidae	Bde	Formicidae	Form	Oonopidae	Oon	Thyrisomidae	Thy
Berytidae	Ber	Galumnidae	Gal	Oppiidae	Opp	Tomoceridae	Tom
Bethylidae	Bet	Gnaphosidae	Gna	Parasitidae	Par	Trhypochthoniidae	Trh
Carabidae	Car	Gryllidae	Gry	Phalangiidae	Pha	Trogiidae	Tro
Carabodidae	Cara	Hypogastruridae	Hyp	Phenopelopidae	Phe	Tydeidae	Tyd
Cercopidae	Cer	Ichneumonidae	Ich	Phlaeothripidae	Phl	Zoodariidae	Zoo
Chrysomelidae	Chr	Isotomidae	Iso	Pholcidae	Pho		
Cicadellidae	Cic	Laelapidae	Lae	Phytoseiidae	Phy		
Corylophidae	Cor	Latridiidae	Lat	Pompilidae	Pom		
Curculionidae	Cur	Leiodidae	Lei	Pseudococcidae	Pse		
Cylisticidae	Cyl	Lepidopsocidae	Lep	Psyllidae	Psy		
Dermanyssidae	Der	Liacaridae	Lia	Ptiliidae	Pti		
Diapriidae	Dia	Linyphiidae	Lin	Rhagidiidae	Rha		